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HARVEST ADVICE FOR PACIFIC SARDINE (*SARDINOPS SAGAX*) IN BRITISH COLUMBIA WATERS FOR THE 2015 SEASON

Context

Pacific Sardine (*Sardinops sagax*) from the Northeast Pacific (California Current) population have a distribution that can range between Baja California and Southeast Alaska. In winter and spring months, most of the Pacific Sardine population resides in waters off the California coast. Prior to, and during summer months, large aggregations of Pacific Sardine migrate from key spawning habitat to more northern waters; the mechanisms behind migratory patterns are unknown but may be affected by population size and oceanographic conditions. Typically, most Pacific Sardine that migrate into British Columbia (BC) waters are the larger and older fish in the population. Pacific Sardine were not observed in 2013 nor in 2014 during the annual summer pelagic trawl surveys conducted in BC waters, nor were any observed by the Canadian commercial Pacific Sardine fleet in either year. The California Current Pacific Sardine population has been declining since a peak in 2007.

In 2013, Fisheries and Oceans Canada (DFO) adopted a new harvest control rule that applies a harvest rate to the estimate of age-1 and older (age 1+) biomass that exceeds 150,000 tonnes to calculate potential harvest (DFO 2013). As described in the 2013 review (DFO 2013), a range in harvest rates (*h*) from 3-5% was selected in the calculation of potential harvest allowances.

This paper provides information on California Current Pacific Sardine population biomass, exploitation rates, commercial landings, and harvest options for the 2015 BC Pacific Sardine fishing season. Specific objectives of this report are to:

1. Report the results of applying the harvest control rule for a range of harvest rates from 0.03 to 0.05 in increments of 0.01
2. Identify uncertainties associated with harvest advice.

This Science Response Report results from the Science Response Process of January 2015 on the Harvest advice for Pacific sardine (*Sardinops sagax*) in British Columbia waters for 2015.

In order for the provided advice to be incorporated into this year's management plan, the previous year's assessment (spring 2014) is being used to calculate harvest options for the 2015 BC sardine season.

A formal Canadian assessment has not been undertaken in 2015 and the following advice is based on multi-year methodology approved in 2013. As such, for a full understanding of Science recommendations, uncertainties, and future considerations, readers are referred to the 2013 CSAS Science Advice Report (DFO 2013).

Background

Population assessment

The United States (US) Fisheries Service of the National Oceanic and Atmospheric Administration (NOAA) assesses the status and population trend of California Current Pacific

Sardine regularly using a Stock Synthesis model (Hill et al. 2012, Hill et al. 2014, Methot and Wetzel 2013). Due to a change in the 2014 US stock assessment and fishery management schedules, full sardine population assessments now occur in the spring and provide biomass estimates for January of the same calendar year and a biomass forecast for July of the same year using input data updated from the previous calendar year. Therefore, data collected from 1993 to 2013 inform the spring 2014 assessment, which generates a January 2014 biomass estimate and a July 2014 forecast of age 1+ biomass.

BC Pacific Sardine fishery harvest control rule

In 2013, Fisheries Management adopted the following harvest control rule that incorporates an estimate of the population's age-1+ biomass $B_{1+,t}$, an escapement buffer, or cutoff value, of 150,000 tonnes, and a harvest rate, h. The cutoff value of 150,000 tonnes is consistent with the cutoff value used in the US harvest guideline. The harvest rate is applied to the difference between the estimated age-1+ biomass and the cutoff. As described in the 2013 review (DFO 2013), a range in harvest rates (h) from 3-5% was selected in the calculation of potential harvest allowances (in tonnes):

$$TAC_{2015} = h\,(B_{1+,t} - 150{,}000)$$

where TAC_{2015} is the potential total allowable catch in 2015. When the estimated age-1+ biomass is less than 150,000 tonnes the recommendation is that there should be no harvest.

This SR provides 2015 BC fishery harvest options based on the spring 2014 US assessment model's biomass forecast for July 2014.

Analysis and Response

Biomass

The estimates of the California Current Pacific Sardine age-1+ biomass show a decreasing trend from over 1 million tonnes in 2007, to between 500,000 and 300,000 tonnes in 2013 and January 2014 (Hill et al. 2014, Dorval et al., 2014; Zwolinski et al., in press). Recent assessments provide no indication of a greater than average year class since 2009 and the 2010 to 2012 year classes were estimated to be among the weakest in recent history (Hill et al. 2014). The 2013 year class estimate is relatively low to average, but poorly estimated (CV=0.73) since it is derived largely from the predicted stock-recruitment curve; the 2013 estimate was included in the calculation of the July 2014 age 1+ forecasted biomass (Hill et al. 2014). The age-1+ biomass maximum likelihood estimate for the July 2014 forecast is 369,506 tonnes (226,411 – 512,601 tonnes, 90% credible interval, Hill et al. 2014).

Pacific Sardine were not observed during the annual pelagic trawl survey conducted by DFO off the west coast of Vancouver Island in 2014 (August 5 to 15) nor in 2013 (August 6 to 16). Estimates of mean Pacific Sardine trawl catch densities (tonnes/km^3) from similar surveys conducted in 2006 and 2008-2012 show a decrease in density during 2008-2012 (DFO 2013).

BC fishery exploitation

The commercial BC sardine fishery was reinitiated in 2002 following a period of closure since 1947 (Ware 1999, DFO 2012). Most fishing has occurred from July to October in association with seasonal migratory behaviour (DFO 2012). From 2002-2012, the annual total allowable catch (TAC), and subsequently the landings, generally increased as a result of management decisions (DFO 2012). Landings were relatively low prior to 2008 (less than 5,000 tonnes), increased from 2009-2012 because of management/policy changes (10,435 - 22,223 tonnes), and were 0 in 2013 and 2014 due to an apparent absence of Pacific Sardine in BC waters

(Table 1). BC exploitation rates were estimated as the annual fishery landings (C_t) divided by the estimated age-1+ biomass in July. The exploitation rate on the stock due to fishing in BC waters increased from ≤ 0.5% prior to 2008 to approximately 3% in 2012 and 0% in 2013-2014 (Table 1). Apical F is the instantaneous fishing mortality rate for fully-selected fish as characterized by the Hill et al (2014) population assessment.

Table 1: Pacific Sardine fishery total allowable catch (TAC) in BC, landings in BC and total landings for the west coast of North America (BC, Washington, Oregon, California and Ensenada Mexico (northern subpopulation only)), as reported in Hill et al. (2014). Also shown are age 1+ population biomass estimates, 2002-2014 (B1+, July; 2014 is a forecast), biomass coefficient of variation (CV), BC exploitation rate, and Apical F for total landings in the population. Total landings (2002-2013) and all July age 1+ biomass numbers are from Hill et al. (2014). All Apical F and 2014 total landings are from Hill (pers. comm., 2014[1]). All TAC, landings, and biomass values are in metric tonnes.

Year	BC TAC	BC Landings (C)	Total Landings	Biomass $B_{1+,\ July}$	CV ($B_{1+,\ July}$)	BC Exploitation ($C/B_{1+,\ July}$)	Apical F
2002	5,040	822	96,344	692,564	14.69%	0.12%	0.35
2003	9,000	1,006	84,311	489,455	16.09%	0.21%	0.13
2004	15,000	4,259	87,699	853,213	14.50%	0.50%	0.17
2005	15,200	3,266	94,149	1,053,120	13.34%	0.31%	0.14
2006	13,500	1,558	91,695	1,364,200	12.27%	0.11%	0.08
2007	19,800	1,507	133,518	1,360,980	12.21%	0.11%	0.13
2008	12,491	10,435	112,195	1,278,360	12.18%	0.82%	0.15
2009	18,196	15,334	99,352	1,085,930	12.51%	1.41%	0.11
2010	23,166	22,223	96,827	1,029,270	12.92%	2.16%	0.10
2011	21,917	20,719	91,268	855,648	13.93%	2.42%	0.17
2012	27,279	19,129	119,198	643,160	16.97%	2.97%	0.21
2013	25,477	0	62,645	437,821	19.71%	0.00%	0.17
2014	17,174	0	29,051	*369,506*	24.20%	0.00%	0.20

Sources of uncertainties

When setting the 2015 BC fishery TAC, DFO fishery management may wish to consider the added uncertainty associated with a July 2014 age 1+ biomass forecast, since the forecast is for July 2014, almost one year prior to the start of the 2015 BC fishing season. Also, the July 2014 forecast is produced with an assessment that is informed by data collected up until 2013. In addition to these uncertainties, Hill et al. (2014) identified stock assessment model uncertainty in quantifying the following:

1. Absolute abundance of recruitment of young fish,
2. A new environment-based index used to address northern and southern subpopulation stock structure and distribution hypotheses,
3. Catchability coefficient of biomass estimates from NOAA acoustic trawl surveys, and
4. Statistical weighting of data from fisheries and research surveys across the time series.

Other uncertainties and concerns that were identified in past DFO CSAS reviews concerning Pacific Sardine (DFO 2013, Flostrand et al. 2015) include:

1. Uncertainty regarding the effect of setting harvest allowances independently of the US and Mexico;

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2. Unknown effects on stock structure and reproductive capacity from fisheries in different regions targeting different age components of the population;
3. Incidental capture of other species in the sardine fishery; and
4. Effects of removing sardine from important forage habitat of sardine predators.

Harvest options

Based on the harvest control rule adopted in 2013, harvest fractions (h= 0.03, 0.04 and 0.05) were applied to a value of 219,506 t; the difference between the July 2014 population forecast biomass (369,506 t) and the cutoff (150,000 t). Resultant harvest amount options ranged from 6,585 to 10,975 tonnes (Table 2).

Table 2: Harvest options (tonnes) resulting from applying harvest rates of 3%, 4% or 5% to the age 1+ forecasted biomass for July 2014 in excess of 150,000 t (219,506 t; Hill et al.2014).

Harvest rate	Harvest option (tonnes)
3.0%	6,585
4.0%	8,780
5.0%	10,975

Conclusions

The U.S. assessment of the Pacific Sardine California Current Pacific Sardine population indicates that biomass appears to be steadily declining. Recent survey and fishery samples, including those collected in 2014, provide no indication of an above average year class since 2009. The absence of a recent strong year class appears to be responsible for decreases in population biomass (Hill et al. 2014).

Predictions of the stock's trajectory are uncertain. Population size and age composition, coupled with coast-wide fluctuations in climate and ocean conditions, contribute to the variability in the timing and extent of seasonal BC Pacific Sardine migration (Emmett et al. 2005, Lo et al. 2010). The interaction of these biological and environmental factors is not well understood and consequently, prediction of seasonal occurrence of Pacific Sardine in BC waters is difficult. Ecological data have been collected and some modeling efforts are underway to better understand these dynamics.

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